EXPLORATION OF VENUS' DEEP ATMOSPHERE AND SURFACE ENVIRONMENT.

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Introduction: Venus formed in the same part of our solar system as Earth, apparently from similar materials. Although both planets are about the same size, their differences are profound. Venus and Earth experienced vastly different evolutionary pathways resulting in unexplained differences in atmospheric composition and dynamics, as well as in geophysical processes of the planetary surfaces and interiors. Understanding when and why the evolutionary pathways of Venus and Earth diverged is key to understanding how terrestrial planets form and how their atmospheres and surfaces evolve. Measurements made *in situ,* within the near-surface or surface environment, are critical to addressing unanswered questions. We have made substantial progress modernizing and maturing pressure vessel technologies to enable science operations in the high temperature and pressure near-surface/surface environment of Venus.

Background: The last two National Research Council Planetary Decadal Surveys [1-3] have called for an *in situ* mission (Venus In Situ Explorer, or VISE) to address high priority questions regarding Venus' atmospheric origin and evolution, deep atmospheric composition, and surface physics and chemistry. The Venus Exploration Analysis Group (VEXAG) has also placed these questions as their highest priorities since the time of its inception in 2005 [4]. Such a mission requires a flight system that can provide direct access to the atmosphere and surface rocks while simultaneously keeping sensitive instruments safe from the harsh Venus environment.

The VISE mission is focused on making key measurements that cannot be made by orbiting remote sensing techniques. These include a range of atmospheric and surface measurements. Most important of these are measurements of the heaviest noble gases, including dramatic improvements in quantifying krypton abundance and the first ever measurements of xenon. The relative abundances of these inert gases, together with high precision measurements of the isotopes of argon, nitrogen, hydrogen, sulfur and carbon provide critical insight into the origin of Venus' atmosphere as well as clues regarding the role of large impacts in its atmospheric evolution.

A definitive measurement of the bulk value for the hydrogen isotopes (D/H) in the deep atmosphere below the clouds is also required to constrain when and at what rates Venus lost its putative early water oceans. Because of a clog in the mass spectrometer inlet, controversy still surrounds the Pioneer Venus D/H measurement. In addition, information on atmospheric trace gas composition within 12 km of the surface is needed to answer questions regarding whether the Venus surface is in equilibrium with the atmosphere or whether there are active sources (e.g., volcanoes?) and sinks that drive the sulfur chemistry cycle. Current knowledge of the deep Venus atmosphere (which contains 2/3 of the Venus atmospheric mass) is based entirely on models, interpolation, and assumptions.

Finally, VISE specifically calls out the need for understanding the physics and chemistry of the crust. Addressing these questions requires imaging of the surface as well as some approach to constraining the chemistry and mineralogy of the surface. First ever measurements of surface mineralogy can address questions of crustal formation (e.g., mafic versus felsic) as well as provide insights into weathering processes.

New Advances: Although *in situ* missions have been flown to Venus in the past, the Soviet VeGa landers flew in 1985, and the United States' Pioneer Venus probes flew in 1978, using technologies and instrumentation capabilities developed in the late 1960's and early 1970's. Because of the long hiatus in Venus *in situ* exploration, the organizations and individuals who built those landers and probes are for the most part no longer available. Thus, any heritage claims to these flight systems is tenuous at best. As a result, *in situ* capabilities must be re-established. This also offers an opportunity to modernize designs to incorporate new materials and approaches that have been developed over the last 45 years.

Over the last several years, we have developed and tested (Figure 1) new technologies using a small (0.5 m) pressure vessel [5-6]. One of the primary challenges of an *in situ* Venus mission is the accommodation of multiple penetrations through the pressure vessel that allow science instruments and engineering components to have access the exterior. For example, instruments such as a mass spectrometer that is essential to measure noble gas abundances and isotopic ratios, requires inlets that allow atmospheric gas to flow from the atmosphere into the instrument's measurement chamber. Thus, building on the successes of our prior effort, we have focused recent work on development of sealing technologies needed to accommodate a range of possible sensors as well as to support engineering needs (e.g., antennas and electrical feed throughs).

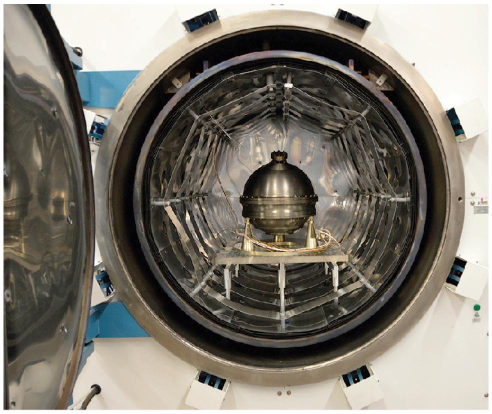

Figure 1. Pressure vessel (0.5 m) tested to Venus surface temperature and pressure conditions.

Over the last year, we have tested multiple components and demonstrated not just the functional capabilities of the individual components, but have also demonstrated the sealing technology needed for each penetration to retain fidelity of the interior environment of the pressure vessel.

Conclusions: Planetary Decadal science objectives for Venus require a pressure vessel to survive the harsh temperature and pressure environment of the Venus surface. Tremendous progress has been made over the last several years to demonstrate the performance of multiple components that require physical access between the interior and exterior of a pressure vessel. The Goddard group are well positioned to build a pressure vessel for surface or near-surface operations that can enable high priority *in situ* science.

References: [1] Crisp, D., *et al.* (2002) *ASP conference Series, 272*, Ed. MV Sykes*,* 5-34. [2] New Frontiers in the Solar System (2003) National Research Council of the National Academies, National Academies Press. [3] Visions and Voyages (2011) National Research Council of the National Academies, National Academies Press. [4] VEXAG (2014) http://www.lpi.usra.edu/vexag/reports/GOI-140625.pdf. [5] Amato, M. *et al.* (2016) *LPSC Abstract #2566.* [6] Amato, M. (2016) *Int. Planet. Probe Wkshp. – 13.*